CLAIMS

1. Method for determining a contact force vector acting on a rolling element bearing (1) in operation, the rolling element bearing (1) comprising an inner ring (6), an outer ring (5) and a number of rolling elements (7) between the inner and outer ring, the method comprising the steps of:
- receiving sensor signals from a plurality of sensors (8) measuring performance characteristics of the rolling element bearing (1);
- processing the received sensor signals to determine the contact force vector,

characterised in that

the plurality of sensors (8) are arranged to measure a bearing component deformation; and the step of processing comprises the step of determining the contact force vector using an inverse transformation of a finite element analysis model which describes the rolling element bearing (1).

2. Method according to claim 1, in which the finite element analysis model is simplified using at least one generalised mode shape, the at least one generalised mode shape being a mathematical description of a natural mode deformation of a component of the rolling element bearing (1), such as the inner or outer ring (5, 6).

3. Method according to claim 2, in which the simplified model has the form:

$$\bar{s}(\omega) = \overline{\overline{T}}_m \overline{\overline{K}}_p^{-1}\left(\frac{\partial F(\bar{\theta},\bar{\alpha})}{\partial \bar{p}}\bar{f}_c(\omega) + \bar{f}_e(\omega)\right)$$

in which

$\bar{s}(\omega)$ is a set of measurement points where the deformations are measured at a frequency ω;

$\overline{\overline{T}}_m$ is a subset of a transformation matrix $\overline{\overline{T}}$ used for the calculation of a stiffness matrix $\overline{\overline{K}}_p$ for the simplified model, the stiffness matrix $\overline{\overline{K}}_p = \overline{\overline{T}}^T \overline{\overline{K}}_{FEM} \overline{\overline{T}}$, $\overline{\overline{K}}_{FEM}$ being a stiffness matrix of a finite element analysis model of the component;

$\bar{p}$ is the vector describing the deformation of the component;

$\bar{\theta}$ is the co-ordinate in circumferential direction of the component;

$\bar{\alpha}$ is the co-ordinate perpendicular to the component;

F is a set of shape functions as used for the simplified modeling of the component;

$\bar{f}_c$ is a vector comprising the contact forces working in points with co-ordinates stored in the vectors $\bar{\theta}$ and $\bar{\alpha}$; and

$\bar{f}_e$ is a vector comprising other forces acting on the component,

and the step of determining the contact force vector $\bar{f}$ comprises the step of solving the simplified model equations for $\bar{f}_c, \bar{\theta}$ and $\bar{\alpha}$ and summing the contact forces according to $\bar{f} = f(\bar{f}_c, \bar{\theta}, \bar{\alpha})$.

4. Method according to claim 3, in which only the sensor signals at a rolling element pass frequency ω_{bp} are considered in the simplified model.

5. Method according to claim 3 or 4, in which the sensors (8)are positioned at the same pitch as the rolling elements (7), and the simplified model takes the form of

$$\left|\bar{s}(\omega_{bp})\right| = \bar{\bar{T}}_m \bar{\bar{K}}_p^{-1} \frac{\partial F(\bar{\theta},\bar{\alpha})}{\partial \bar{p}} \left|\bar{f}_c(\omega_{bp})\right|,$$

and the step of determining the contact force vector $\bar{f}$ comprises the step of solving the simplified model equations for $\left|\bar{f}_c\right|$ and $\bar{\alpha}$ and summing the contact forces according to $\bar{f} = f(\bar{f}_c, \bar{\alpha})$.

6. Method according to one of the claims 3, 4 or 5, in which the number of sensors (8) is equal to the number of rolling elements (7).

7. Method according to one of the claims 3, 4 or 5, in which the contact angle of the forces acting on the rolling element bearing (1) is equal to a predetermined value, and the number of the plurality of sensors (8) is equal to the number of loaded rolling elements (7).

8. Sensor arrangement for determining a contact force vector acting on a rolling element bearing (1) in operation, the rolling element bearing (1) comprising an inner ring (6), an outer ring (5) and a number of rolling elements (7) between the inner and outer ring,

the sensor arrangement comprising processing means (10) and a plurality of sensors (8) connected to processing means, and the processing means (10) being arranged to execute the method steps according to one of the claims 1 to 7.

9. Sensor arrangement according to claim 8, in which the processing means (10) comprise a neural network, the neural network being trained to provide the contact force vector as an output using input signals from the plurality of sensors (8).

10. Sensor arrangement according to claim 8 or 9, in which the bearing inner ring (6) or outer ring (5) are attached to a sensor holder (2), a circumferential recession being provided between at least part of the contacting surfaces of the inner ring (6) or outer ring (5) and the sensor holder (2).